

Beam Stabilization Project Planning, FY08 - FY12 - DRAFT

Glenn Decker, February 2008

In October of 2005, a white paper entitled “Five-year plan for APS beam stabilization” was put forward by John Carwardine, Frank Lenkszus, Glenn Decker, and Om Singh. This paper enumerated specific goals and an upgrade path aimed at achieving these goals in a 5-year time frame. Since that time, a number of projects recommended in the white paper have been at least partially funded, while others were deferred. The intent of this article is to provide a brief status report on work completed to date, describe how best to proceed toward our ultimate goals, and show how this work ties in with other important facility upgrades.

At the time it was written, the white paper asserted that “the APS no longer provides the best orbit stability amongst the three large third-generation light source worldwide”. In the case of SPring-8, the focus has been on the passive elimination of beam disturbances which has resulted in vertical rms motion 40% lower than the APS in at least one instance. At ESRF, a new fast global orbit feedback system was commissioned in 2004, resulting in closed-loop bandwidth extending up to 150 Hz, compared with the aging APS system which has a bandwidth of about 60 Hz. As a result, rms noise at ESRF is a factor of 2 or more lower than at APS, in the frequency band from 0.1 to 200 Hz. Shown in Table 1 is a comparison of AC performance between the three facilities.

Table 1: RMS Beam Motion, 0.1-200 Hz

	APS 2008	ESRF c. 2005	SPring-8 c. 2004
Horizontal (μm)	4.8	1.2 - 2.2	3 - 4
Vertical (μm)	1.6	0.8 - 1.2	1

While the APS is lagging in the area of AC orbit stability, it is the only facility of the three which takes advantage of insertion device photon beam position monitors on a large scale. As a result, a majority of APS insertion device beamlines enjoy long-term pointing stability better than 0.6 microradians peak-to-peak over a 24-hour period. Direct comparisons of long-term pointing stability with ESRF and SPring-8 are difficult because they have not invested significantly in photon beam position monitoring, and rf bpms located near the source don't have the resolution or stability to track sub-microradian-scale drift. One of the challenges articulated in 2005 was to extend this level of long-term stability to the one-week time scale, including reproducibility following machine studies periods. Shown in Table 2 are the beam stability goals quoted from the October 2005 white paper.

Table 2: APS Beam Stability Goals

	AC Motion, 0.1 - 200 Hz		Long-term Drift, (One week)	
	microns rms	μrad rms	microns p--p	μrad p-p
Horizontal	3.0	0.53	5.0	1.0
Vertical	0.42	0.22	1.0	0.5

The scope of this plan is explicitly restricted to particle beam centroid motion as opposed to higher-order moments of the particle beam distribution like beam size and tilt, which are covered in a separate set of imaging diagnostics proposals. Further, motions occurring faster than about 200 Hz are also not considered here, such as multibunch and other fast instabilities. Separate machine improvement proposals will address these fast feedback systems. Improvements to top-up operation including injector upgrades, while improving the stability of x-ray intensity, are also not covered.

PROJECT STATUS

Shown in Table 3 is a list of projects recommended in 2005 with a brief summary of their status.

Table 3: Project status

	Project Status as of 2/27/2008
BH4 Corrector Relocation	4 out of 30 units relocated (with Operations funds)
Tunnel Temperature Upgrade	Phase 1 Complete
Power Supply Smart Interface Board	Deferred
X-bpm System Enhancement	Phase 1 80% complete
Portable Beamline Detector	Phase 1 complete
Fast Digitizer for Narrowband, X-ray bpms	Deferred
Monopulse rfbpm Upgrade	Two sectors complete, parts in hand for four more
Real-time Feedback Digital Signal Processor upgrade	Deferred

BH4 Corrector Relocation

While this project was never officially funded through the APS project proposal process, a simple mechanical design was completed and implemented in four sectors (20, 22, 23, and 24). This provides the capability for testing necessary real-time feedback software modifications to allow two fast steering correctors / sector / plane vs. one presently (AH3). Simulations have indicated a significant improvement in noise suppression with double the corrector coverage.

Tunnel Temperature Regulation Upgrade

This task is complete, and tunnel temperature variation is now less than ± 0.6 degrees F (± 0.33 degrees C). As stated in October 2005, the initial goal was to improve tunnel temperature regulation to “well within a peak-to-peak of ± 1 Celsius”, and this has been accomplished. The long-term goal of ± 0.1 degrees Celsius still remains to be achieved.

Power Supply Smart Interface Board

While some early design work was conducted on this non-funded proposal, recent thinking envisages a large-scale effort to modernize the storage ring power supply regulation and control system interface systems. As such, it is part of a separate proposal, which must be closely integrated with a parallel modernization of the real-time feedback system processing and infrastructure. Plans for the power supply upgrade, while still in their early stages, are ahead of those for real-time orbit feedback, however regular meetings are being conducted with the power supply, controls, and diagnostics groups to assure a positive outcome.

X-bpm System Enhancement

A total of \$119k was allocated to this project (Project 131-05, WP#01202-00-131), with two separate objectives: a refurbishment of the existing ultraviolet-sensitive photon bpms and the development of a detector which is sensitive only to hard x-rays. A total of seventeen UV bpms have been upgraded, with ten units remaining for conventional front-ends, and three completely new units are needed for canted undulator beamlines. Hard x-ray bpm development has indicated that it is challenging to apply the same pin-diode detector geometry as has been successfully demonstrated using monochromatic x-rays, owing primarily to the large beam size. In addition to collecting significant quantities of useful data with the arrangement constructed at 19-ID-C, a novel technique involving vibrating wires as extremely sensitive temperature diagnostics was successfully tested there. The vibrating wire monitor work was a result of an international collaboration with scientists at the Yerevan Physics Institute in Armenia, and has been recognized by winning the Faraday Cup Award, sponsored by Bergoz Instrumentation, which is to be presented at the 2008 Beam Instrumentation Workshop. This technique has been extended to an in-air design, presently installed at an un-used bending magnet exit port flange in sector 37. Finally, a design for a pin-diode-based hard x-ray flux monitor is complete, and procurement and fabrication activities are underway with the aim of installing this unit in beamline 35-ID. This design should provide an absolute datum for determining the alignment of high-power insertion device beams.

Portable Beamline Detector Suite

The hardware portion of this project (Project 481-06, \$133k) is complete, and control software development is 80% complete. This diagnostic is designed to provide a uniform measurement of beamline flux, spectrum, and stability characteristics, with bandwidth covering the range from thermal drift to mechanical vibration. Tests with beam are expected during operating periods 2008-01 and 2008-02.

Fast Digitizer for Narrowband, X-ray bpms

This project was deferred and should be incorporated with future efforts to modernize the real-time feedback system. Among other features, the sampling rate will be increased by more than a factor of ten, from 1.5 to 20 kHz.

Monopulse rfbpm Upgrade

The monopulse rf bpm system was designed in 1992 and installed in 1994, and as such this upgrade addresses both AC beam stability and machine obsolescence issues. The primary benefit from this upgrade will be a reduction in electronics noise floor, to well below the 420 nm rms 0.016-200 Hz beam stability requirement. This project was approved for FY07 (project 527-07,

WP# 01205-00-131, \$205k) to modernize the data acquisition system associated with the broadband (monopulse) rf beam position monitor system. Development is complete, and a full sector of electronics is in the final stages of the commissioning process in sector 38. Hardware for a total of 6 sectors is in hand and will be deployed early in FY09, following assembly and check-out.

Real-time Feedback Digital Signal Processor Upgrade

This proposal was deferred, however the recommendations made in the October 2005 white paper are still supported by AES-CTL (F. Lenkszus in particular).

PROJECT PLAN

The above list of projects should remain as priority items, with some modifications based on experience to data, and at least one addition.

The Rogue Microwave Problem^{1,2}

In 1997, a set of beam-excited spurious microwave modes mimicking vertical beam motion in the large-aperture storage ring vacuum chambers were discovered. While these modes tend to affect the curved vacuum chambers most strongly, they are present at some level in all of the large-aperture chambers. Various ideas were investigated to solve this problem, including the use of lossy ceramics and shorting plungers to damp or otherwise modify the modes. Some of these ideas had merit, and could likely be done relatively inexpensively, but were never implemented since they required breaking vacuum for each of the 200 vacuum chambers affected. The solution to date has been to rely on rf bpms attached to the insertion device vacuum chambers which do not have this problem, in addition to making use of bending magnet and insertion device photon beam position monitors for vertical DC orbit correction. The bpms which are affected by these modes are still useful for AC feedback.

In a nutshell, this project plan supports the recommendations from October 2005, with the addition of a solution to the rogue microwave problem and a shifting of the power supply upgrade to a separate machine upgrade / obsolescence proposal.

1. The BH4 corrector relocation project should be completed.
2. A plan for further improving tunnel temperature regulation should be implemented
3. The power supply upgrade should be implemented, coordinated closely with plans for real-time feedback
4. Upgrades to the ultraviolet photon bpms should be completed, and deployment of a hard x-ray position-sensitive detector should proceed.
5. The portable beamline detector should be commissioned and upgraded to track fast beam motion and beam size variations.
6. Fast digitizers for the narrowband and photon beam position monitors should be procured.
7. Complete the monopulse rf bpm upgrade.
8. Complete the upgrade of the real-time feedback system to allow a sample rate of 20 kHz, access to two correctors / sector for most sectors, and at least 8 beam position monitors per sector.
9. Begin a rogue microwave remediation plan.

¹ <http://accelconf.web.cern.ch/AccelConf/p99/PAPERS/THP61.PDF>

² http://www.aps.anl.gov/Facility/Technical_Publications/lsnotes/ls299.pdf

Summary of Beam Stability Project Costs

Shown in Table 4 are some historical and forecast cost data associated with these beam stabilization projects. In some cases the (tunnel temperature, real-time feedback system) the costs to complete will require further analysis, while in others, like the monopulse rfbpm upgrade, experience to date provides a reasonably accurate estimate.

Table 4: Beam Stability Costs to Date and Projections

	Funds Allocated to Date	Estimated Total M&S, October 2005, Unburdened	Estimated Cost to Complete, Unburdened
BH4 Corrector Relocation	\$0	\$200k	\$181k
Tunnel Temperature Upgrade	\$900k*	\$560k	\$4.1M**
Power Supply Smart Interface Board	\$0	\$467k	NA
X-bpm System Enhancement	\$119k	\$565k	\$1.25M
Portable Beamline Detector	\$133k	\$243k	\$182k
Monopulse rfbpm Upgrade	\$205k	\$632k	\$585k
Fast Digitizer for Narrowband, X-ray bpms	\$0	\$250k	\$600k
Real-time Feedback Digital Signal Processor upgrade	\$0	\$315	
Rogue Microwave Solution	\$0	\$0	\$440k

* Used non-AIP project funds

** WAG estimate

Listed below are milestones largely reflecting the October 2005 plan, modified to incorporate progress to date. Many of the descriptions in the existing project proposal database are still relevant, and project numbers are noted as applicable.

MILESTONES

Year 1

- Deploy the Noise Abatement and Beamline Stability teams.
- Start relocating BH4 steering corrector magnets to available spool-piece locations to increase the number of fast correctors available to the real-time orbit feedback system. During studies, characterize improvements to orbit feedback algorithms. This will likely use reduced sampling rate until faster processors are installed. [Project Proposal #471]

- Begin deploying upgraded monopulse bpm electronics [Project Proposal #527].
- Benchmark the performance of commercially available ‘Libera’ digital bpm electronics against the performance of the newly developed in-house prototype monopulse bpm upgrade electronics.
- Finish development and characterization of new ‘Gold Standard’ x-ray bpm and flux monitor. [Project Proposal #492]
- Develop fast DSP/FPGA VME processor board for real-time feedback processing. [Project Proposal #455]
- Start developing a high precision fast analog digitizer board for sampling of Narrowband rf bpms and x-ray bpms. [Project Proposal #532]
- Complete commissioning of portable detector suite for beamline stability diagnostics [Project Proposal #481]; initiate design phase of upgraded version.
- Develop design and remediation plan for to eliminate rogue microwave modes.

Year2

- Finish developing a high precision fast analog digitizer board for sampling of Narrowband rf bpms and x-ray bpms.
- Continue deployment of upgraded monopulse bpm electronics
- Start deploying new high performance processors and reflective memory networks.
- Deploy new ‘Gold Standard’ hard x-ray flux monitor at several key locations; produce final version of high-power non-destructive bpm.
- Commission phase 2 modifications to portable beamline diagnostic.
- Develop design for +/- 0.1 degree C tunnel temperature regulation system.
- Implement rogue microwave solution in two sectors.

Year 3

- Finish deploying new fast analog digitizer boards.
- Complete deployment of upgraded monopulse bpm electronics.
- Move to a fully integrated DC/AC real-time orbit feedback system; support the Datapool and ‘slow’ orbit correction systems for local steering and studies purposes.
- Increase orbit feedback sampling rate to 15-20KHz for routine operations and with the full 320x8 orbit correction matrix.
- Implement SR air handling system Phase-2 upgrades to provide peak-to-peak temperature excursions of +/- 0.1 degree C.
- Start widespread deployment of ‘Gold Standard’ x-ray bpms.
- Continue to implement rogue microwave solution.

Year 4

- Implement tight air temperature control for bpm electronics racks on the storage ring mezzanine.
- Continue to implement rogue microwave solution.

Year 5

- Complete widespread deployment of 'Gold Standard' x-ray bpms.
- Continue to implement rogue microwave solution.